CONSTRUCTION DEFLATORS AND MEASUREMENT OF OUTPUT

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Through the system of national accounts a wide range of macroeconomic data is available, such as output, national income and expenditure. From the national accounts indexes of output per person employed and output per hour worked are derived, giving the basic measures of labour productivity. There are a range of issues associated with the macroeconomic measurement of production, output and labour, capital and multifactor (MFP) productivity. This paper focuses on specific measurement problems found in the deflators used in estimating the value of construction output. The purpose of this paper is to review deflators in general and construction deflators in particular, and to identify the major problems found in adjusting current prices to constant prices using these deflators. The topics covered include deflation techniques, measurement of output quality and capital inputs, and the use of input price indexes. A range of alternative construction cost indexes and deflators identified in the UK and US literature are discussed, and the extent of similarities between all these indexes identified. The approach taken is to, firstly, discuss the general characteristics of deflators and the problems that are commonly recognized in their application, and secondly, to analyse the features of deflators in the context of measurement of the output of the construction industry.

Keywords: price indexes, deflation, construction output.

INTRODUCTION

The adjustment of current prices by a deflator, or price index, to produce constant price estimates of output, is used in the national accounts to give estimates of 'real' changes in output. Deflation is used to remove inflationary effects from economic data and give changes in output in terms of quantities produced, and national accounts data on economic growth and contributions to growth by various parts of the economy is typically presented in this constant dollar format. Economic growth is usually defined as growth in real gross domestic product (GDP), presented as constant price estimates of output measured as value added (i.e. net of intermediate inputs) with associated price indexes. This provides indexes of outputs, therefore issues associated with index numbers and their use has been the subject of considerable debate in the literature (e.g. Fischer and Shell 1972).

While the methodology is straightforward, the scope and inclusiveness of the price data used to construct GDP deflators is not. The US Price Statistics Review Committee (Stigler Report 1961) recommended that hedonic price indexes be investigated as a better method of dealing with the major problem associated with deflation, which is quality change. The hedonic method uses regression techniques to estimate the value of quality changes, the major issue in deflation, and to interpolate missing values (Triplett 1990 comprehensively discusses hedonic indexes). The

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hedonic hypothesis is that heterogeneous (distinctively different) goods are an aggregation of characteristics, while the conventional treatment of goods rests on a simple price/quality tradeoff.

SOURCES OF BIAS IN AGGREGATE PRICE INDEXES

Real GDP growth is biased upward with constant price estimates because of their use of fixed weights for the Consumer Price Index (CPI), and the CPI was found to be biased upward in a major study for the Senate Finance Committee in the US (Boskin Report 1996). The main reasons for that study's conclusion that the CPI has a substantial upward bias were substitution bias and quality change.

Substitution bias arises because the CPI is a Laspeyres price index (i.e. base weighted) that measures price changes for thousands of different products and then aggregates these separate measures of price change using weights that apply to a base year (or years). The weights in the CPI are based on a consumer expenditure survey done up to five years before the base year. Therefore the CPI is based not on current spending patterns but rather on expenditures in that base year. Studies of this substitution bias in the CPI have a consensus estimate of a quarter of a percent a year (Gordon 1995:157).

Also, the CPI fails to adjust adequately for the improved quality of new products and new models. The 'product cycle' has new products initially made in small volumes and sold at high prices, but over time volumes increase and prices reduce. It often takes many years for new products to be included in the CPI basket, and no account is made for improvements in the quality of existing products over time. Gordon estimates this bias at 0.6% per year (Gordon 1995: 158).

The Boskin Report (1996) divided the CPI into 27 categories and calculated the effect of quality change for each one. A major part of the final report discussed the changes in the quality of US housing over the years, finding that houses had become larger and better equipped (i.e. their quality was significantly better), and therefore recommended adjustment of the treatment of housing cost.

The implications of price index bias for measuring building and construction output are significant. In regard to substitution bias, the problems found in adjusting for changes in the relative use of factors of production in construction deflators has had the effect of introducing an upward bias to estimates of construction output when materials prices increase faster than labour costs. This has often been the case since the 1960s, and has had the effect of reducing construction labour productivity growth.

Research by Cassimatis (1969) showed that over the period 1947-64 there was significant substitution between factors of production. The US industry was found by Cassimatis to have an elasticity of substitution of nearly one, and as the relative prices of capital and labour changed input of capital and labour also changed. In particular, while heavy construction output increased by 100%, employment increased by 65%, and the sector tripled its use of construction equipment. Building increased output by 90%, employment by 47% and doubled its use of construction equipment (Cassimatis 1969: 100). These changes in the capital intensity of the industry are not picked up in the labour productivity measures of output per hour worked and output per person employed. Koch and Moavenzadeh (1979) also found increasing use of plant and equipment in highway construction.

CONSTRUCTION DEFLATORS

In producing the national accounts, one of the most difficult areas is the deflation of construction expenditure. Output of the building and construction industry is estimated by deflating current prices by input price indexes. Pieper (1990) follows the Stigler Report (1961), Gordon (1968, 1995) and others in arguing that deflation by input price indexes does not produce accurate estimates of output at constant prices. Pieper concludes that, for the US "Evidence indicates an overdeflation of construction of at least 0.5% per year between 1963 and 1982. While a 0.5% annual overdeflation may appear to be modest, if true, it would have major consequences." (Pieper 1990: 252-53). Overdeflation will reduce both the estimate for value of output of the construction industry and the industry's contribution to GDP growth.

Input price indexes are averages of materials prices and wage rates, which are intermediate inputs, applied to completed buildings and structures, which is the output. The main problem with input price indexes is that they assume a constant relationship between input and output over time, the assumption of no change in productivity is built in to them. This means that, if productivity is increasing, input price indexes will be upwardly biased.

The Price Statistics Review (Stigler Report 1961) criticized the use of input price indexes for deflating construction expenditure, as being unrepresentative of the inputs priced and geographical coverage, and being based on inaccurate weights. The Stigler Report (1961: 29) recommended a significant increase in research on construction deflation, and suggested a residential deflator based on the price per square foot of a range of categories of new homes. This led to the adoption by the US Bureau of Economic Analysis (BEA) in 1968 of a new, hedonic price index for housing.

Cassimatis (1969) also argues that price indexes for construction are unlike those for manufacturing industries, because a value index based on unit numbers at market prices cannot provide adequate deflators for construction:

> study of construction engineering literature suggests that substantial increases in productivity have taken place in recent years because of more versatile equipment, increased off-site fabrication, and better construction management ... the feeling persists that construction productivity is greater than the measurements show ... largely due to the fact that there are no adequate price indexes that can be used as deflators of the gross product originating in construction (Cassimatis 1969: 79-80)

Cassimatis (1969) used the custom built nature of construction products as the basis of his defense of the industry's productivity record. Similarly, Rosenfielde and Mills (1979: 94) argue that "construction durables are almost inevitably heterogeneous". Pieper argues that the problem of construction deflation is due to the "extreme hetrogeneity" of structures, because most structures are unique (Pieper 1990: 239). This is an important argument, because application of a single deflator to heterogeneous goods, especially durable goods, overlooks the differences in quality and function between different buildings and structures.

US DEFLATORS

The most extensively studied deflators are those for the United States construction industry. Pieper (1990) reviews the history of construction deflation by the US Bureau of Economic Analysis (BEA) between 1961 and 1988. The major revision to the BEA deflators was in 1974, when six input price indexes were dropped and three indexes added. Two of the new indexes were based on the price of work put in place, thus avoiding the problems of input price indexes and improving the overall performance of the deflator. Since 1974 there have been a series of further modifications to BEA deflation methodology, however Pieper finds that:

> The BEA has made little progress in reducing the use of "proxy" indexes. The term proxy index is used here to refer to an index based on a different sector of construction than the one it is used to deflate … About half of new construction is deflated by indexes based on other sectors, or nearly the same percentage as in 1961. The main sectors lacking their own deflators are multiunit residential construction and most types of non-residential buildings.
> A more stringent criterion for evaluating the construction deflators is the percentage of construction deflated by both a price (output) index and a non-proxy index. Only about one third of new construction meets both criteria … Seen in this light, progress in construction deflation has been quite limited over the past 40 years … Little or nothing is known of price movements in the important non-residential building, public utility, and multiunit residential sectors. (Pieper 1990: 244).

CANADIAN DEFLATORS

Lowe (1995) describes the use of estimation indexes by Statistics Canada for a price index for non-residential buildings. Five different types of non-residential buildings (office, warehouse, small shopping center, light industrial building and high school) and new apartment buildings are divided into five elements (architectural, structural, mechanical and electrical trades, and contractor's overhead and profit). Using surveys mostly sent to subcontractors, around 100 different items are priced for each building type by Statistics Canada, using estimated prices obtained from contractors. Each of the five elements has its own index, with the mechanical and electrical trades deflated using a combination of materials price indexes and wages adjusted for productivity (on the basis of the subcontractor surveys). The index for overhead and profit is extremely volatile, therefore the overall index is more sensitive to changes in competitive conditions than conventional construction price indexes. Lowe comments that:

> *The long-term advantage is that productivity changes that occur within individual trades (including general contracting) are reflected in the price; although, as the specifications for each building are held constant for many years, any productivity improvement in the design of the building itself is not captured. A disadvantage is that the prices are hypothetical, but even so they show far more sensitivity in the short term through trade cycles than do input indices. These indices have been produced since 1978, and as the input indices were continued for many years the differences between the two can be calculated* (Lowe 1995: 155).

Over the whole period 1972 to 1994 the difference is 0.9% a year, though there were larger differences from year to year as the output index is more sensitive to the business cycle. Since 1990, as inflation in Canada has fallen, the gap between input and output indices across the cycle has not been enough to overcome the gap that the output index builds up in the expansionary part of the cycle. However, the introduction of the output price indices did not greatly affect the deflation of non-residential construction expenditures. Prior to the availability of this index, a constant estimate for productivity improvement was made to the input index in deflating this element of expenditure, which averaged about the same amount, so the introduction of this series only changed the estimate of constant price values through the trade cycle, smoothing them out somewhat.

UK PRICE INDEXES

Ferry *et al.* (1999) devote a chapter to cost indexes. This includes a review of the approaches to constructing factor cost and tender price indexes. The authors describe five methods for compilation of a building cost index. The first two methods use Bills of Quantities and are described as not reliable Ferry *et al.* (1999: 178). A third method is the analysis of unit prices or the cost per square meter of buildings of a similar type and function, applicable to buildings which are “homogeneous in function and standard and for which there is a regular building programme to provide the data” c 178). The data found in cost books such as Rawlinsons (2001) *Australian Cost Handbook* or *Riders Digest* (Rider Hunt 2001) gives cost per square meter by building type, and past issues can be used for comparison. The cost per square meter approach has been used in international comparisons of construction industry performance and costs by the Construction Industry Development Board in Singapore (CIDB 1989) and the Industry Commission in Australia (Industry Commission 1991).

A factor cost index uses changes in the cost of resources required for a typical building in a composite index. The resources are labour, measured by wages, materials, measured by cost, and plant, weighted by type and priced by hire rates, purchase price and depreciation, or maintenance. Each resource is weighted by importance, typical values given are: labour 35 - 45%; materials 50 - 60%: and plant 5 - 10% (Ferry *et al.* 1999: 182). The two problems identified with a factor cost index are adjustment for changes in labour productivity, which will not be included in the index if weightings are not changed, and the overhead and profit of contractors, which are a function of market conditions and difficult to quantify.

In the United Kingdom (UK) there are a number of factor cost indexes available. Ferry *et al.* (1999) list two Department of Environment and the Regions (DETR) indexes, a price adjustment formulae and a tender price index. They also describe a number of Building Cost Information Service (BCIS) indexes: nine building cost indexes for specific types of work (steel frame, concrete frame, brickwork, mechanical and electrical etc.), and a tender price index. There is also a Davis Langdon and Everest tender price index (Ferry *et al.* 1999: 186-91).

A tender-based index (Ferry *et al.* 1999:: 183-85) captures market conditions because it uses tender documents (the lowest tender received) as the source of information. The index comes from the pricing of the same tender documents using standard rates at base year prices, to give an increase or decrease in cost in the current tendering market. The drawbacks are the questionable validity of Bill of Quantity rates, and obtaining priced bills for jobs that are comparable except for date of tender. The advantages of this type of index are that it measures the cost to the client of a project, and it is not based on other indexes. The disadvantages are the need for a large sample of projects to avoid bias, and the reliance on the base year schedule, which has to be regularly revised to take new products into account

ALTERNATIVE CONSTRUCTION DEFLATORS

Although Ferry and Brandon are discussing cost indexes that can be used by quantity surveyors, they cover the range of indexes available. In particular, alternative deflators are generally either factor cost or tender-based indexes. Pieper (1990) surveys and compares four alternative construction deflators that have been developed by researchers in the US, and they do fall into the categories used by Ferry and Brandon. The first is an alternative private non-residential building index introduced by the BEA in 1966 (BEA2 in Table 1 below) after the critical comments made in the Stigler Report (1961). This was a weighted average of five indexes with about one-third based on output/cost indexes, that was “probably only a marginal improvement over the BEA composite” (Pieper 1990: 248).

A second deflator for the US, by Dacy (1965), was based on a price index for materials and an estimate of the share of materials in output. This deflator assumes that real construction output is proportional to real materials usage, and does not allow for substitution between materials and other factors of production due to changes in relative prices. Pieper gives Dacy’s index as:

$$P^c = P^m/b \qquad \text{Equation 1}$$

where P^c is the construction price index, P^m is a materials price index, and b is an index of the share of nominal materials in nominal construction (Pieper 1990: 249). The main problem with this index is in estimating the materials share of output, a value that is not found in the data available. Gordon (1968) created an index that was an unweighted average of Dacy’s index and an index he called the component-price index (CPH), based on the ratio of price and cost indexes for structural steel and structural concrete. This index has the form

$$CPH = CI^c(P^{ss}/CI^{sc} + P^{ss}/CI^{ss})/2 \qquad \text{Equation 2}$$

Where CI is a cost index, P is a price index for materials in place, and c, sc and ss are building construction, structural concrete and structural steel respectively. By using the ratio of structural steel and structural concrete price indexes to their cost indexes, Gordon allows for changes in productivity, although he suggests that concrete and steel may have had more rapid efficiency improvements than other construction components (Gordon 1968: 422).

The fourth alternative deflator was by Allen (1985), using a price per square foot index for deflating non-residential building. Allen assumed that the price per square foot is a good proxy for output. However Allen notes that this index does not adjust for improvements in design or the increase in mechanical and electrical services share of building costs.

Pieper also used a price per square foot index to deflate non-residential buildings, based on office buildings, and residential buildings under 2,400 square feet. Pieper followed Dacy, Gordon and Allen in using the Federal Highways index as the base for deflation of non-building construction. Table 1 shows the annual rates of growth of these deflators.

Table 1 below shows that there is limited agreement between these alternative deflators on the rate of increase in construction prices and costs. The differences between the deflators is due to the different weightings given to the component indexes and/or the base of the indexes. Despite the similarities in the deflators used for non-building construction, there is some variation between them. For the other deflators, considerable variations are found, particularly for non-residential building. Clearly, there is no one best method for deflating construction, and different methods can produce a significant range of estimates. Each method has its strengths and weaknesses, and these appear to vary across the industry sectors and types of construction.

Pieper suggests that the solution may be in using estimation indexes for construction (1990: 255-258). These would use estimates from contractors or cost engineers for the cost of a hypothetical but fully specified building. Estimation indexes can price either the whole structure (the aggregate approach), which would be done by one firm, or components of the structure, which could be done by a number of firms. Pieper concludes that "the disaggregated approach would be best for complex types of structures while the aggregated approach would be best for simpler structures" (1990: 258).

Table 1: Annual Percentage Rates of Change of Alternative Construction Deflators in the US 1963-82.

Deflator	1963-82	1963-72	1972-82
Total Construction			
BEA	7.0	4.9	9.0
BEA2	7.1	5.5	8.6
Dacy	6.2	3.6	8.5
Gordon	6.5	4.8	8.2
Allen	7.3	4.3	10.0
Pieper	6.3	4.2	8.2
Residential Construction			
BEA	7.0	4.4	9.4
Gordon	6.5	4.8	8.1
Allen	6.9	4.1	9.5
Pieper	6.5	4.2	8.7
Non-residential Building			
BEA	7.0	5.3	8.6
BEA2	7.3	5.7	8.6
Gordon	6.5	4.8	8.1
Allen	7.8	4.1	11.4
Pieper	6.2	3.9	8.3
Non-building Construction			
BEA	7.1	4.9	9.0
BEA2	6.9	5.0	8.6
Gordon	6.6	4.6	8.4
Allen	7.0	4.8	9.0
Pieper	6.1	4.4	7.6

Source: Pieper 1990: 252

In his discussion of alternative construction deflators Pieper (1990) observes that:

> *The obvious advantage of estimation indexes is that they can control for construction heterogeneity, by keeping the specifications fixed over time. Their main weakness is that they are based on hypothetical prices rather than actual transaction prices. Contractors submitting hypothetical bids know that they will not be required to construct the project in question. They also do not have the normal incentive of bidding as low as possible in order to win the project. Under these conditions, they may bid differently than they would on an actual project* (Pieper 1990: 256).

The Stigler Report (1961) recommended against use of estimate indexes because of their use of hypothetical projects with fixed specifications.

CONCLUSION

There is an extensive literature on deflators, the problems of deflation, and the effects on estimates of construction output of commonly used deflators. The issues raised by the use of price indexes for deflation have not been solved to date, and appear to have no simple, or readily available solutions. These include the fact that the deflator used to adjust for price changes will systematically overstate the rate at which prices increase and underestimate growth in output if indices for labour and material costs are used instead of output price indices (which are generally not available)..

This is probably the main reason for the low rate of measured productivity growth in construction. It is the favored explanation by the majority of industry analysts, such as Cassimatis and Allen, largely because of the deficiencies found in construction deflators. If real construction value added has been underestimated due to the deflators used, construction productivity growth has also been understated. The major problem identified with construction deflators is the downward bias given to output estimates through overdeflation due to the lack of adjustment for quality changes in the buildings and structures delivered by the industry. Also, the application of a single deflator to heterogeneous goods, especially durable goods, overlooks the differences in age, quality and function between different buildings and structures. This problem becomes more severe with long-life assets like buildings and structures.

The inability to capture quality changes in the buildings and structures delivered by the construction industry has also adversely affected the measurement of productivity. As the energy efficiency and quality of finishes has improved, and as the share of building costs due to mechanical and electrical services has increased over time (providing greater amenity), the deflators used have not been adjusted to take these trends into account. In effect, the deflators assume there has been no change in the quality of buildings.

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